(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 237 222 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
04.09.2002 Bulletin 2002/36

(51) Int Cl.7: H01P 1/15, H04B 1/44

(21) Application number: 01104812.1

(22) Date of filing: 27.02.2001

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(71) Applicant: TELEFONAKTIEBOLAGET LM ERICSSON (publ)
126 25 Stockholm (SE)

(72) Inventor: Kodim, Walter
90489 Nürnberg (DE)

(74) Representative: Schmidt, Steffen J., Dipl.-Ing.
Wuesthoff & Wuesthoff,
Patent- und Rechtsanwälte,
Schweigerstrasse 2
81541 München (DE)

(54) **Multiband transformation stage for a multiband r.f. switching device**

(57) A multiband transformation stage (14) comprising a common first signal port (20), a common second signal port (26) and a signal path (50) coupled between the first signal port (20) and the second signal port (26) is described. The signal path (50) is switchable between a first state with a first quarter-wavelength transformer characteristic for a first frequency band, a second state with a second quarter-wavelength transformer characteristic for a second frequency band and a third state with a transmission characteristic. The invention also relates to a multiband switching device comprising the multiband transformation stage (14) and at least one of a high-power stage (12) and a low-power stage (16).

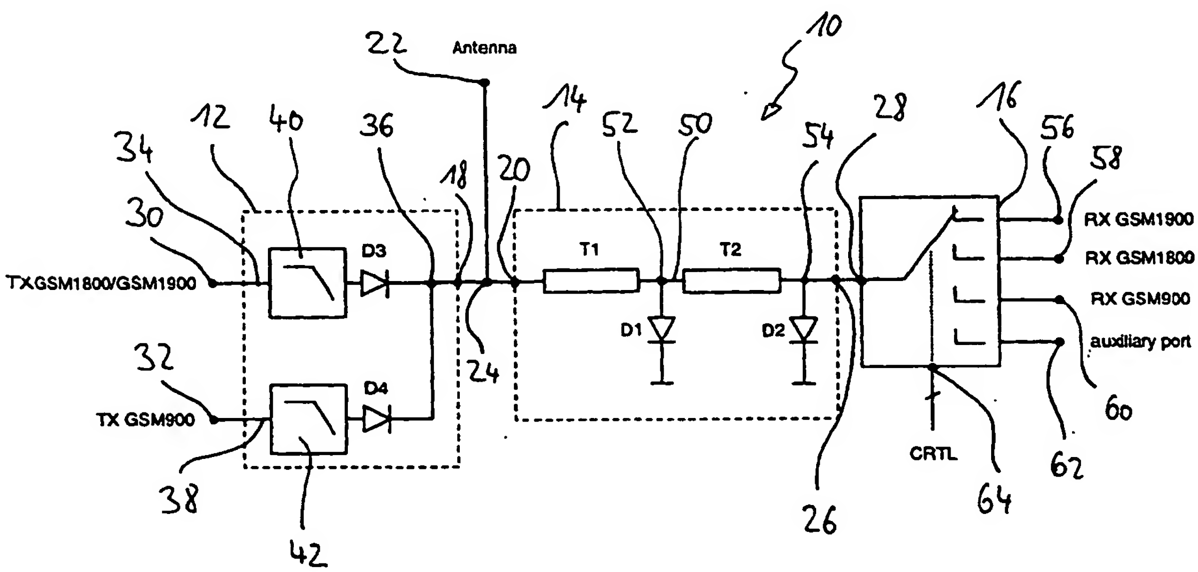

Fig. 3a

P 1 237 222 A1

ш

Printed by Jouve, 75001 PARIS (FR)

elements SE4 and SE5 are switched off. Switching element SE3 thus creates a short circuit at a node 110. This short circuit is transformed by the quarter-wavelength transmission line SL1 to an open circuit for the second frequency band at signal input 102. In a third operational state corresponding to receiving in the first frequency band, switching elements SE3, SE4 and SE5 are turned off. Consequently, first signal output 104 is coupled impedance-matched via the two quarter-wavelength transmission lines SL1, SL2 with signal input 102. In a fourth operational state corresponding to receiving in the second frequency band, switching element SE3 is turned off and switching elements SE4, SE5 are turned on. This means that second signal output 106 is coupled impedance-matched via first quarter-wavelength transmission line SL1 with signal input 102. Further, the short circuit created by switching element SE5 is transformed by second quarter-wavelength transmission line SL2, which has a quarter-wavelength characteristic for the second frequency band, into an open circuit at second output port 106.

[0010] The fourth operational stage necessitates that the two quarter-wavelength transmission lines SL1, SL2 have an identical transformation characteristic. This requirement, however, limits the applicability of the multiband transformation stage 100 depicted in Fig. 2 to the case where the first frequency band equals approximately half the second frequency band. A further disadvantage of the multiband transformation stage 100 is the fact that in the fourth operational state, i.e. in high-band receive mode, two switching elements SE4, SE5 are in an on state. This leads to a considerable current consumption in the order of milliamperes and reduces the stand-by time of battery-powered devices. Moreover, the multiband transformation stage 100 comprises altogether three switching elements SE3, SE4, SE5 which have to be biased. This requires a comparatively complex biasing network. The biasing network becomes even more complex if the multiband transformation stage 100 has to be adapted for triple-band applications.

[0011] Also, the multiband transformation stage 100 suffers from limited isolation between signal input 102 which may be coupled to transmitters and signal outputs 104, 106 which may be coupled to receivers. This means that terminations of signal outputs 104, 106 become relevant in the first two operational states, i.e. in transmit modes. Terminations of output ports 104, 106, however, are difficult to design due to the constraints imposed by the receivers coupled to output ports 104, 106.

[0012] There is, therefore, a need for a multiband transformation stage which does not suffer from the limitations of prior art multiband transformation stages. There is further a need for a multiband switching device comprising such a multiband transformation stage.

SUMMARY OF THE INVENTION

[0013] The existing need is satisfied according to the invention by a multiband transformation stage comprising a first common signal port, a second common signal port and a signal path coupled between the first common signal port and the second common signal port, the signal path being switchable between a first state with a first quarter-wavelength transformer characteristic for a first frequency band, a second state with a second quarter-wavelength transformer characteristic for a second frequency band and a third state with a transmission characteristic for at least the first frequency band and the second frequency band.

[0014] The multiband transformation stage according to the invention can be used in all multiband environments that require a coupling of an electrical component to an input/output port in a first mode (third state of the multiband transformation stage) and a decoupling of the electrical component from the input/output port in a second mode (first state and second state of the multiband transformation stage). Preferably, the multiband transformation stage is used to decouple in a transmit mode a multiband transmitter switch, which is coupled to an antenna port, from a multiband receiver switch or a multiband transmitter/receiver switch, which is coupled to the antenna port via the multiband transformation stage.

[0015] The multiband transformation stage may easily be adapted to more than two different frequency bands, for example to triple-band or quadruple-band applications. In this case the signal path may be switchable among further states, each further state corresponding to an individual quarter-wavelength transmission characteristic for an individual further frequency band. If frequency bands are only slightly spaced apart, however, a single state may be allocated to such frequency bands since a state having a quarter-wavelength transmission characteristic for one of these frequency bands will also have a fairly good quarter-wavelength transmission characteristic for nearby further frequency bands.

[0016] According to the invention, a signal fed in the third state into the multiband transformation stage via one of the common signal ports is transferred to the other common signal port regardless of its frequency. If desired, individual signal paths for individual frequency bands may therefore be selected only after the signal is output by the multiband transformation stage. For example, one common signal port may be split up into several individual ports. Since the signal path needs not necessarily be selected within the multiband transformation stage there are less constraints with respect to the construction of the multiband transformation stage. This allows a less sophisticated and a more flexible realization of the multiband transmission stage.

[0017] For example, the third state of the signal path can be realized without the need to turn any switching elements on. The power consumption in the third state can thus be kept very low. Moreover, the use of the multiband transfor-

it becomes possible to use low-power MMIC devices, i.e. standard MMIC devices already available from a large number of suppliers at a comparatively low price. MMIC low-power switches have the additional advantage that the number of second signal ports of the low-power switch can easily be increased up to five or more. The number of e.g. signal output ports is thus no longer restricted by the design of the multiband transformation stage. Moreover, the power consumption of MMIC devices is comparatively low. Therefore, the overall power consumption of the multiband switching device is also low, especially when the switching elements of the multiband transformation stage are switched off.

[0027] Modular MMIC low-power stages can advantageously be combined with modular multiband transformation stages and high-power stages constructed in multi-layer technology or with discrete components. The modular concept allows a multi-sourcing of the individual modular stages from different suppliers and is thus suitable for very high volume products. Moreover, the modular concept minimizes design risks since the modular stages of the multiband switching device can be split up and verified separately. Also, the modular concept leads to more flexibility in printed circuit board (PCB) design due to the possibility of splitting of the individual modular stages.

[0028] The multiband switching device is preferably employed as an antenna switch in mobile telephones. The low-power switch can thus be configured as a multiband receiver switch. Also, the low-power switch may be configured as a multiband transmitter/receiver switch provided that the multiband transmitter/receiver switch is subjected to only low transmit powers. Thus, low-power transmit signals may be fed into the antenna switch via the low-power stage. The high-power stage can comprise a multiband transmitter switch.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] Further aspects and advantages of the invention will become apparent upon reading the following detailed description of a preferred embodiment of the invention and upon reference to the drawings, in which:

Fig. 1 is a schematic diagram of a prior art single band antenna switch;

Fig. 2 is a schematic diagram of a prior art dual-band antenna switch;

Fig. 3a is a schematic diagram of a triple-band antenna switch according to the invention;

Fig. 3b is a schematic diagram of a quadruple-band antenna switch according to the invention;

Fig. 4 is a schematic diagram of a basic simulation setup for the triple-band antenna switch of Fig. 3;

Fig. 5 is a table showing simulation models and data sets used for the simulation setup of Fig. 4; and

Fig. 6 shows the simulation results of the simulation setup of Fig. 4.

DESCRIPTION OF A PREFERRED EMBODIMENT

[0030] In Fig. 3a a schematic diagram of a first embodiment of a multiband switching device according to the invention in the form of a triple-band antenna switch 10 is illustrated. The antenna switch 10 is part of a mobile telephone operable in three frequency bands in accordance with GSM 900, GSM 1800 and GSM 1900.

[0031] The antenna switch 10 depicted in Fig. 3a has a modular structure and consists essentially of a high-power stage 12, a multiband transformation stage 14 and a low-power stage 16. A signal output 18 of the high-power stage 12, a first signal port 20 of the multiband transformation stage 14 and an input/output port configured as antenna port 22 are each coupled to a node 24. A second signal port 26 of the multiband transformation stage 14 is connected to a signal input port 28 of the low-power stage 16.

[0032] The high-power stage 12 is constructed in multi-layer technology and is used as a multiband transmitter switch. It comprises a first signal input 30 and a second signal input 32 coupled to respective transmitters not depicted in Fig. 3a. The first signal input 30 is used as common GSM 1800 / GSM 1900 signal input, i.e. as high-band signal input. The second input 32 is used as GSM 900 signal input, i.e. as low-band signal input. A first high-power signal path 34 is coupled between the high-band signal input 30 and a node 36. A second high-power signal path 38 is coupled between the low-band signal input 32 and the node 36. Each high-power signal path 34, 38 comprises a low-pass filter 40, 42 followed by a switching element in the form of a pin-diode D3, D4. The low-pass filters 40, 42 reduce the level of spurious transmitter signals at harmonic frequencies. The high-power stage 12 further comprises an individual biasing network not depicted in Fig. 3 for each pin-diode D3, D4. Each biasing network may be configured like the biasing network depicted in Fig. 1.

[0033] The multiband transformation stage 14 has a single signal path 50 which connects the first signal port 20 and

specified in e.g. the GSM standard. In the antenna switch 10 according to Fig. 3a transmitter signals present at node 24 are sufficiently attenuated by the amount of isolation provided by the multiband transformation stage 14 such that spurious signal generation within the low-power stage 16 is kept small even without taking further measures.

[0041] In the high-band and low-band transmit modes the low-power stage 16 is switched such that the signal output 26 of the multiband transformation stage 14 is coupled to the auxiliary port 62 which is terminated with a specific impedance. Such a fixed termination is advantageous because it has been found that stop-band attenuation of the low-pass filters 40, 42 arranged within the high-power stage 12 is effected by the impedance present at node 24. Best transmission performance is achieved when the system impedance of for example 50 Ohm is present at node 24. In the prior art depicted in Fig. 1, however, it was observed that unused ports like the signal outputs 104, 106 coupled to both the signal input 102 and corresponding receivers exhibit a varying impedance in the transmit modes. This is due to the fact that receiver filters lead to a mismatch at the signal outputs 104, 106 in the transmit mode. A varying impedance at the signal outputs 104, 106, however, may modify the impedance of the switching elements SE3, SE4, SE5 of the multiband transformation stage 100 such that no effective short circuit is created. Thus no proper transformation to an open circuit impedance at the signal input 102 of the multiband transformation stage 100 can be achieved. This usually effects the matching of the respective transmitters as well as the performance of low-pass filters within a high-power stage coupled to the signal input 102.

[0042] This problem of prior art antenna switches is overcome by the implementation of the auxiliary port 60 which allows a fixed termination of the signal output 26 of the multiband transformation stage 14 in transmit modes. By activating the auxiliary port 60 the impedance at node 24 can thus be kept constant. Any transmitter signal will therefore be attenuated due to the isolation provided by the multiband transformation stage 14 and additionally by the isolation of the low-power stage 16 with activated auxiliary port 60. The maximum input power requirements of the receiver filters can be decreased accordingly. High-power receive saw filters are therefore no longer necessary. The size of saw filter structures can thus be reduced. Furthermore, advantages for multi-burst transmit modes as required by general packet radio systems (GPRS) arise.

[0043] Up to now the low-band and the high-band transmit mode have been illustrated. Next, the receive mode will be described. The receive mode corresponds to the third state of the signal path 50 within the multiband transformation stage 14. In the receive mode, all pin-diodes D1, D2, D3, D4 are switched off. Therefore, power consumption of the antenna switch 10 is very low in the receive mode.

[0044] Since both pin-diodes D1, D2 of the multiband transformation stage 14 are switched off in the third state, the two transmission lines T1, T2 can be considered as a pure transmission line without quarter-wavelength transformer characteristic. In the receive mode, one of the signal output ports 56, 58, 60, i.e. a respective receiver, is coupled to the antenna port 22 in an impedance-matched manner.

[0045] In Fig. 3b a schematic diagram of the second embodiment of a multiband switching device according to the invention in the form of a quadruple-band antenna switch 10 is illustrated. The antenna switch 10 is part of a mobile telephone operable in four frequency bands in accordance with GSM 450, GSM 900, GSM 1800 and GSM 1900. The antenna switch 10 depicted in Fig. 3b has some similarities with the antenna switch of Fig. 3a. The same reference numbers are thus used for corresponding components.

[0046] Again, the antenna switch 10 depicted in Fig. 3b has a modular structure and comprises a high-power stage 12, a multiband transformation stage 14 and a low-power stage 16. The high-power stage 16 is constructed in multi-layer technology and is used as a multiband transmitter switch having a first signal input 30 coupled to a GSM 450 transmitter and a second signal input 32 coupled to a GSM 900 transmitter.

[0047] The multiband transformation stage 14 is constructed in multi-layer technology. A first transmission line T1 of the multiband transformation stage 14 is configured to have approximately a quarter-wavelength characteristic for the frequency band of 900 MHz corresponding to GSM 900. A second transmission line D2 of the multiband transformation stage 14 is configured such that the two transmission lines T1 and T2 together have approximately a quarter-wavelength characteristic for the frequency band of 450 MHz corresponding to GSM 450.

[0048] The low-power stage 16 is configured as transmit/receive switch matrix with a single signal input/output port 28 coupled to a second signal port 26 of the multiband transformation stage 14, four signal output ports 56, 58, 60, 66, a signal input port 68, an auxiliary port 62 and a control signal input 64. The signal output ports 56, 58, 60, 66 are coupled to a 1900 MHz receiver, a 1800 MHz receiver a 900 MHz receiver and a 450 MHz receiver, respectively. The receivers are not depicted in Fig. 3a. The auxiliary port 62 is terminated with a pre-defined impedance.

[0049] The input port 68 of the low-power stage 16 is coupled to either a GSM 1800 transmitter path or to a GSM 1900 transmitter path of a transmitter stage not depicted in Fig. 3b. The maximum transmit power occurring at the signal input 68 is 30 dBm. Thus, the low-power stage 16 may be configured as a GaAs MMIC transmitter/receiver switch matrix. Usually, such GaAs MMIC devices can handle powers up to approximately 30 dBm. Therefore, the value of 30 dBm can serve as a limit with respect to low-power and high-power signals. In future, MMIC devices operable at higher powers will become available. Thus, the limit between low-power signals and high-power signals may shift accordingly.

wherein the low-power stage is a low-power switch (16) having a first signal port (28) coupled to the second signal port (26) of the multiband transformation stage (14) and a plurality of second signal ports (56, 58, 60, 62, 66, 68) which may be coupled to the first signal port (28) of the low-power switch.

7. The multiband switching device according to claim 5 or 6, wherein the low-power stage (16) has at least one signal port (62) terminated with a pre-determined impedance.

8. The multiband switching device according to one of claims 5 to 7, wherein the low-power stage (16) is a MMIC device.

9. The multiband switching device according to one of claims 5 to 8, wherein the low-power switch is a multiband receiver switch (16) or a multiband transmitter/receiver switch.

10. The multiband switching device according to one of claims 5 to 9, further comprising a high-power stage (12) coupled to the first signal port (20) of the multiband transformation stage (14).

11. A multiband switching device (10) comprising a multiband transformation stage (14) according to one of claims 1 to 4 and a high-power stage (12) coupled to the first signal port (20) of the multiband transformation stage (14).

12. The multiband switching device according to one of claims 10 or 11, further comprising an input/output port, preferably an antenna port (22), coupled to the high-power stage (12) and the first signal port of the multiband transformation stage (14).

13. The multiband switching device according to one of claims 10 to 12, wherein the high-power stage is a multiband transmitter switch (12).

14. The multiband switching device according to one of claims 10 to 13, wherein the high-power stage (12) is constructed in multi-layer technology or with discrete components.

15. A low-power switch (16) for a multiband switching device (10), the low-power switch having a first signal port (28) and a plurality of second signal ports (56, 58, 60, 62, 66, 68) which may be coupled to the first signal port (28), wherein at least one signal port (62) is terminated with an impedance which is chosen such that a node (24) of the multiband switching device (10) is terminated in an impedance-matched manner.

16. A mobile telephone comprising the multiband switching device (10) according to one of claims 5 to 14, the multiband switching device (10) being configured as antenna switch.

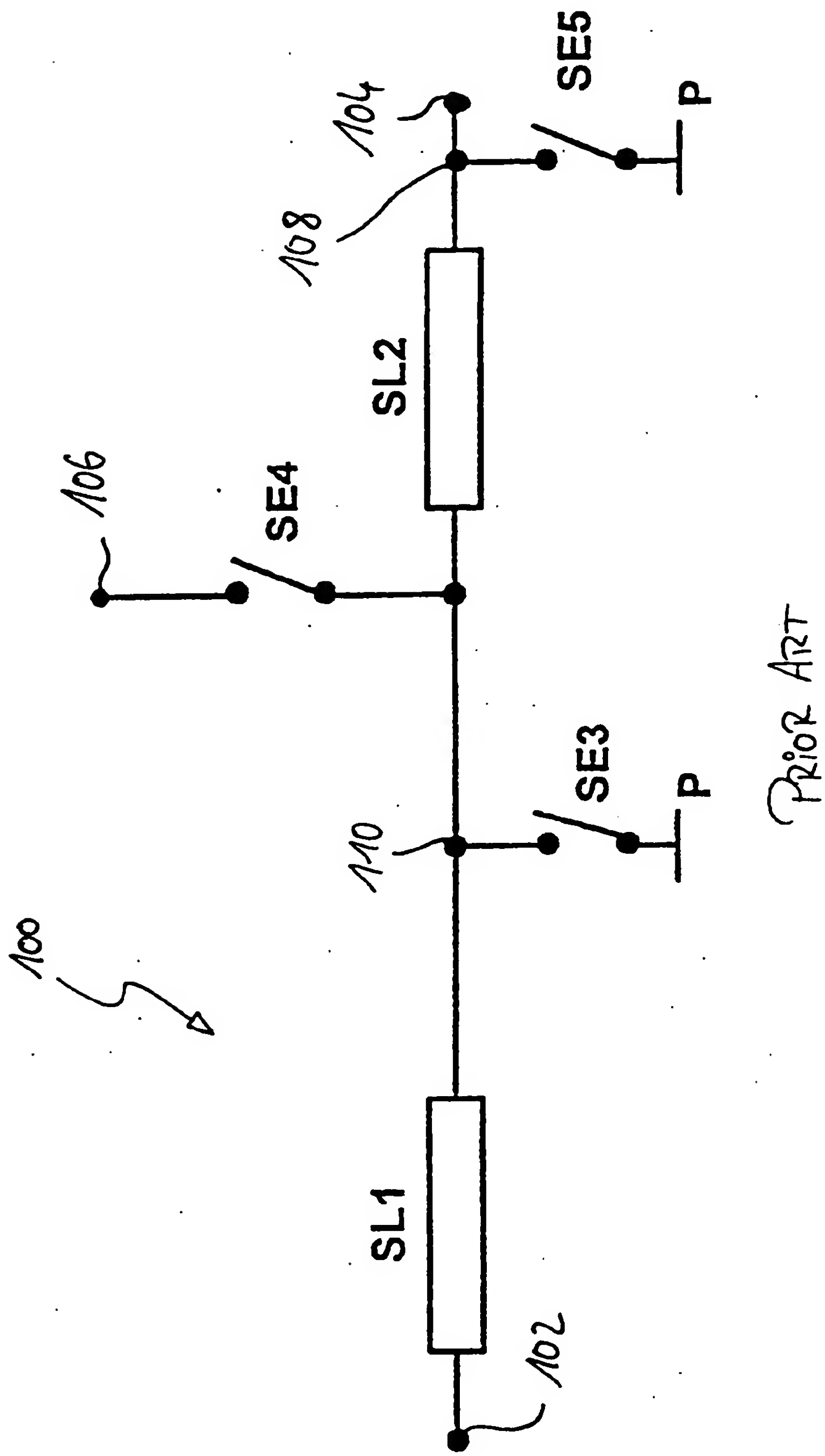

Fig. 2

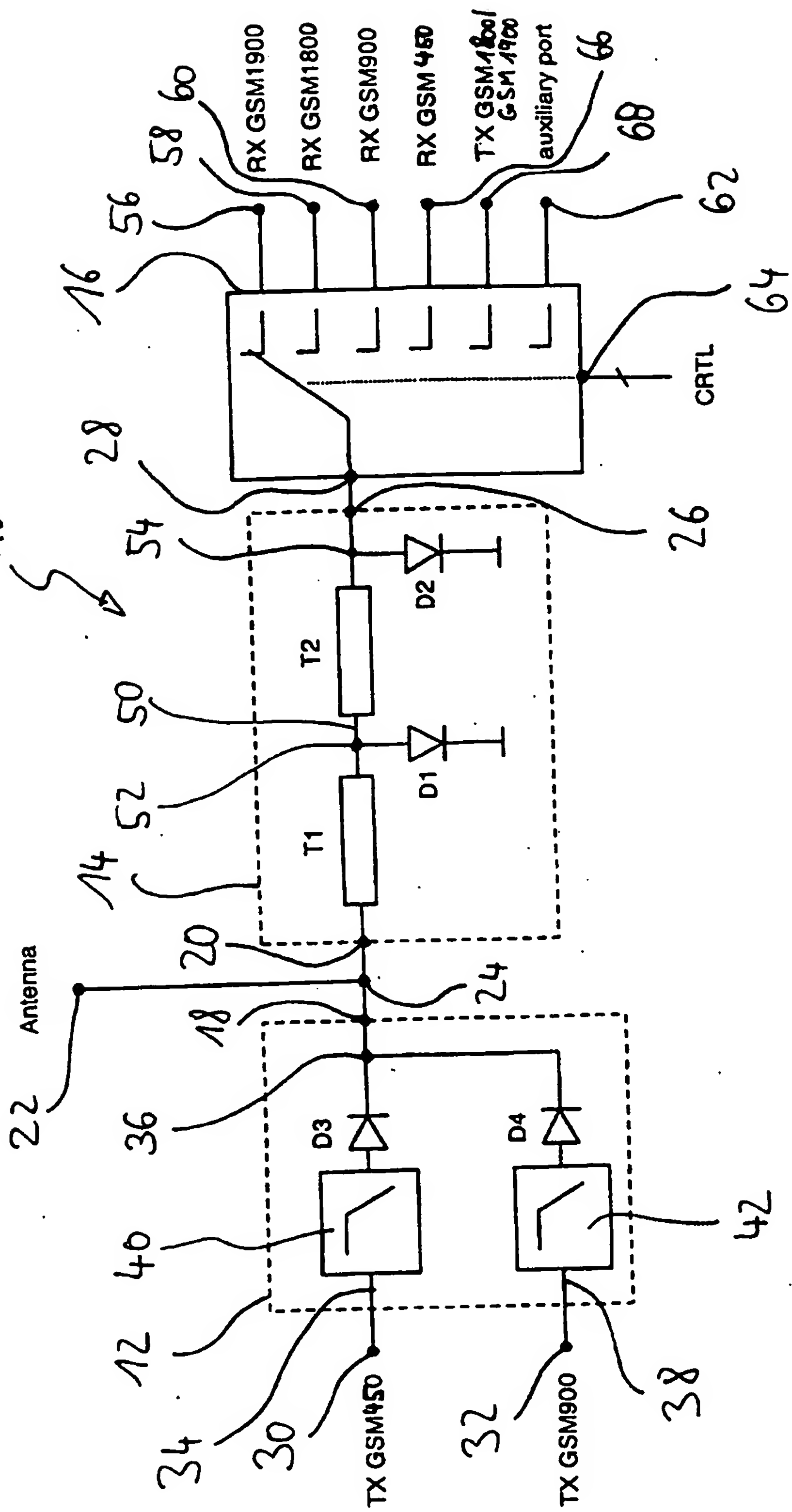
RX GSM1900
RX GSM1800
RX GSM900
RX GSM 450
TX GSM1800
GSM 1900
auxiliary port
CRTL
Antenna
T1
T2
D1
D2
D3
D4
TX GSM450
TX GSM900
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
50
52
54
56
58
60
62
64
66
68

Fig. 3b

MULTI-BAND ANTENNA SWITCH Simulation models / data sets	Description
PIN-diode BAR63	Measurement result, s-parameter data set, OFF state: = I_{PIN} = 0mA, no backbiasing ON state: = I_{PIN} = 20mA
TL1, TL2	HPADS model Micro-strip line model, Er=4.2, TanD=0.033
L3, L4	HPADS inductor model, L1=L2=47nH, Q=5
C1, C2	HPADS ideal capacitor model, C1= 6.5pF, C2=33pF

Fig. 5

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 10 4812

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	WO 00 41326 A (MOTOROLA INC) 13 July 2000 (2000-07-13) * the whole document *	1-16	H01P1/15 H04B1/44
A	WO 00 49675 A (SCHMIDT GERHARD R ;SIEMENS AG (DE)) 24 August 2000 (2000-08-24) * page 5, line 23 - page 7, line 20 * * abstract * * figures 2,7 *	1-16	
A,D	DE 197 04 151 C (SIEMENS AG) 27 August 1998 (1998-08-27) * page 3, line 7 - page 5, line 63 * * figures 1,2 *	1-4	
A	PATENT ABSTRACTS OF JAPAN vol. 2000, no. 03, 30 March 2000 (2000-03-30) & JP 11 340872 A (KYOCERA CORP), 10 December 1999 (1999-12-10) * abstract *	1-3	TECHNICAL FIELDS SEARCHED (Int.Cl.7)
A	PATENT ABSTRACTS OF JAPAN vol. 1997, no. 09, 30 September 1997 (1997-09-30) & JP 09 139601 A (FUJITSU LTD), 27 May 1997 (1997-05-27) * abstract * * figures 7-12 *	1-3	H01P H04B
A	EP 0 446 050 A (SONY CORP) 11 September 1991 (1991-09-11) * column 5, line 57 - column 7, line 9 * * abstract * * figure 7 *	1-3	

-/--

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
MUNICH	11 July 2001	von Walter, S-U

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 01 10 4812

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

11-07-2001

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 0041326 A	13-07-2000	AU 2380300 A	24-07-2000
WO 0049675 A	24-08-2000	NONE	
DE 19704151 C	27-08-1998	CN 1195239 A	07-10-1998
		EP 0862279 A	02-09-1998
		JP 10313266 A	24-11-1998
		US 6021318 A	01-02-2000
JP 11340872 A	10-12-1999	NONE	
JP 09139601 A	27-05-1997	NONE	
EP 0446050 A	11-09-1991	JP 2830319 B	02-12-1998
		JP 3258126 A	18-11-1991
		DE 69121263 D	19-09-1996
		DE 69121263 T	06-02-1997
		US 5193218 A	09-03-1993
EP 0578160 A	12-01-1994	DE 69307412 D	27-02-1997
		DE 69307412 T	12-06-1997
		JP 6077707 A	18-03-1994
		US 5442812 A	15-08-1995
DE 19919368 A	16-11-2000	AU 1261800 A	17-04-2000
		WO 0019626 A	06-04-2000

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82